Is Performance of Intermittent Intense Exercise Enhanced by Use of a Commercial Palm Cooling Device?

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Abstract

Walker, TB, Zupan, MF, McGregor, JN, Cantwell, AR, and Norris, TD. Performance of intermittent intense exercise enhanced by use of a commercial palm cooling device? *J Strength Cond Res* 23(9): 2666–2672, 2009—The purpose of this study was to determine if using the CoreControl Rapid Thermal Exchange (RTX), a commercial palm cooling device, during active rest periods of multiple set training is an effective means to increase performance. Ten volunteers (5 men, 5 women) completed a $\dot{V}O_2$max test on a motorized treadmill and 3 interval running tests on a human powered treadmill. This treadmill allowed the subjects to quickly reach their running speed while allowing for measurement of distance, speed, and force. During the interval running tests the subjects completed eight 30-second intervals at a hard/fast pace followed by a 90-second walking or light jogging recovery period. During the recovery period, the subjects placed their left hand on 1 of 3 media: the RTX held at 15°C (R), a 15°C standard refrigerant gel pack (P), or nothing at all (C). Although there were differences in core temperature (T_c), subjective heat stress ratings, distance, and power generated between intervals, there were no significant differences ($p < 0.05$) found between treatments for any of these variables, nor was the interaction effect of interval*treatment found to be significant. Mean distance completed per trial was 717.1 m ± 124.4 m (R), 724.8 m ± 130.3 m (P), and 728.6 m ± 110.6 m (C). Change in T_c from baseline to end-test averaged 1.41°C ± 0.37°C (R), 1.41°C ± 0.39°C (P), and 1.41°C ± 0.59°C (C). There were no significant differences ($p < 0.05$) in T_c, heart rate (HR), or $\dot{V}O_2$ between intervals or treatments. We conclude that the RTX, in its current iteration, is ineffective at improving performance and/or mitigating thermal stress during high-intensity intermittent exercise.

Key Words thermal stress, running performance, mechanical cooling

Introduction

Although it may be potentially advantageous to locally warm working muscle for high-intensity exercise performance (2,14,20), a large increase in core body temperature (T_c) may adversely affect such exercise and delay recovery. It is well established that hyperthermia during exercise increases cardiovascular strain (10) and elevates hormones associated with stress and fatigue (19) such as cortisol, prolactin, and catecholamines. Body core temperature greater than 40°C generally results in the inability to continue exercise despite the lack of other central fatigue causal factors (e.g., inadequate substrate, abnormal pH) (17,18).

Thus it appears that delaying and/or limiting an increase in T_c during high-intensity intermittent exercise (e.g., weight-training, interval training) may provide the ability to exercise for a longer duration and/or at a higher intensity. Immersion of the hands in cold water has been demonstrated to be an effective method for mitigating exercise-induced increases in T_c (9,12,15) but may be tempered as a result of vasoconstriction. Generally, when exposed to cold, vasoconstriction occurs in the effected extremity, reducing blood flow and effectively limiting local heat exchange.

The Rapid Thermal Exchange (RTX) Core Control Device (AVAcore Technologies, Ann Arbor, Michigan, U.S.A.) aims to overcome this limitation by using a proprietary combination of cooling the hand (to 15–28°C) while applying a 35- to 45-mm Hg vacuum to open peripheral anastomoses and enhance hand blood circulation. The intended result is a greater heat exchange than with cooling alone. Two investigations (11,13) have reported that use of the RTX enhanced cooling and/or mitigated thermal stress during exercise more successfully than no cooling (13) or hand cooling alone (11). Additionally, the company that

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Table 1. Demographic characteristics of the participants (mean ± *SD*).

	Height (m)	Mass (kg)	Age (year)	$\dot{V}O_2$peak (ml·kg^{-1}·min^{-1})	km train per week
Men ($n = 5$)	1.77 ± 0.09	79.0 ± 5.3	31.9 ± 9.8	52.4 ± 2.3	30.2 ± 10.6
Women ($n = 5$)	1.62 ± 0.11	61.5 ± 4.8	28.0 ± 7.0	44.8 ± 5.3	33.1 ± 3.4
Total	1.69 ± 0.11	70.6 ± 9.5	29.9 ± 8.6	48.6 ± 3.8	31.7 ± 7.8

manufactures the RTX has reported anecdotal evidence of athletes increasing repetitive set training volumes by extremely large amounts when using the device between sets and/or intervals.

The Air Force Research Laboratory previously tested the efficacy of the RTX device under simulated pilot heat stress and found it to be slightly more effective than control conditions, although less effective than a water-cooled vest (3). The current study was designed to determine whether the RTX could enhance the physical training regimens of Air Force Special Operators (AFSO) in their regular participation in high-intensity multi-set and multi-interval sessions as part of their physical fitness training. Our hypothesis was that use of the RTX would mitigate the increase in core temperature (T_c) during high-intensity interval training, resulting in greater work and/or training volume/duration per exercise session.

Methods

Experimental Approach to the Problem

Volunteers completed 3 trials of loaded interval running. In 1 of the trials the RTX was used on the left hand during recovery intervals, in another trial subjects placed their left hand on a cold pack during recovery, and in the third trial subjects placed their left hand on an empty shelf during recovery. All subjects received all 3 treatments, and trial order was randomized. Work and power output, along with physiological variables such as T_c and heart rate, were compared between conditions.

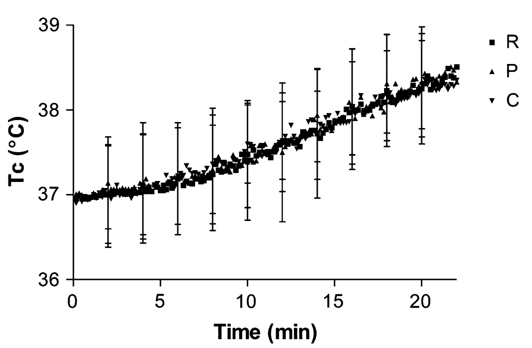

Figure 1. T_c over time for 3 treatments: RTX (R), ice pack (P), and control (C) for $n = 10$.

Subjects

Ten (5 men and 5 women) moderately fit volunteer subjects, 18 to 44 years of age (mean age of 29.9 years), completed this 3-trial, repeated-measures design protocol. Subjects were not especially heat acclimated. However, they were all native to the south-central United States and data collection took place in early autumn. Subject descriptive characteristics are displayed in Table 1. All subjects met the American College of Sports Medicine's low-risk classification (1) for exercise testing.

The Wright Site Institutional Review Board approved this research study to allow the use of human subjects. Prior to participation, subjects were informed of the risks and discomforts associated with this study and their written informed consent was obtained.

Procedures

After consent was given, a medical screening/clearance was performed by the medical monitor. Once medically cleared, each volunteer completed an 8- to 12-minute incremental treadmill $\dot{V}O_2$ peak test. During the $\dot{V}O_2$ peak test, each volunteer walked for 2 minutes at 2 miles per hour on a Woodway Desmo treadmill (Woodway, Waukesah, Wisconsin, U.S.A.) and then began running at a preselected pace for an additional 2 minutes. This pace ranged from 8.8 to 13 km/hour^{-1} (5.5 to 8.0 miles/hour^{-1}) and was based on the training information provided by each volunteer. This running speed was held constant for the remainder of the test. All additional intensity was imposed by increasing the grade 1 or 2% each minute until the volunteer reached volitional fatigue. Plastic facemasks were worn during the entire test to collect expired gases that were analyzed using the Parvo Medics' TrueOne 2400 Metabolic Cart (Parvo-Medics, Sandy, Utah, USA). Following the $\dot{V}O_2$ peak test each volunteer had a 10-minute recovery period. During this recovery, subjects were shown the RTX and practiced using it.

After the recovery period, each volunteer walked and ran on the Woodway Force Treadmill for about 10 minutes at several self-selected speeds/loads to gain familiarization with this unique treadmill. The Force Treadmill is a human-powered

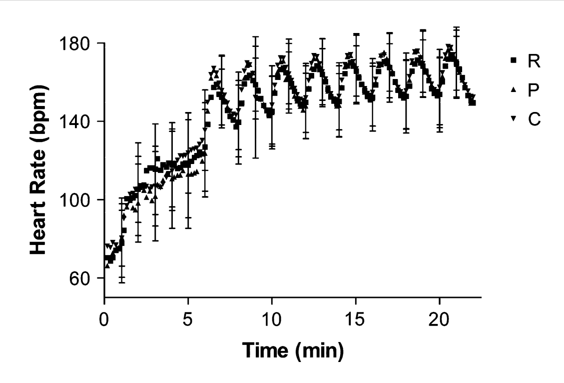

Figure 2. Heart rate over time for all 3 treatments: RTX (R), ice pack (P), and control (C) for $n = 10$.

treadmill on which the runner wears a harness connected to a force transducer that allows for the measurement of force and, therefore, work and power.

Volunteers' health status and current body weight were recorded on their arrival for the remaining 3 visits. Body weight within 0.5 kg of previous weight was used to ensure similar levels of hydration between trials. Each trial was separated by at least 48 hours and was conducted in a relatively normothermic environment of 21 to 23°C and 30 to 50% RH. Subjects were required to wear the same clothing for all 3 trials. Once cleared, the volunteer ingested a CorTemp Telemetry System (HQ Inc, Palmetto, Florida, U.S.A.) capsule. This capsule was taken in unison with a Power Bar and 500 mL of water to speed digestion/motility. (The water bolus also helped ensure proper hydration.) The capsule transmits a low-frequency radio signal that varies with body temperature, and the information is picked up by a handheld recorder. This system is widely used in environmental physiology research; is less invasive and more comfortable than rectal or esophageal thermisters; and has been demonstrated to be a valid, accurate tool (8).

Following a 45-minute seated rest period to allow the capsule to reach the intestinal tract, each volunteer was fitted with a plastic facemask for expired gas collection, a waist belt used to connect the volunteer to the Force treadmill, and a heart rate monitor. A 1-minute pre-test rest period followed to check that all signals were being recorded properly.

Each volunteer then completed a 5-minute warm-up at a very light to light intensity, 10 on the Borg Rate of Perceived Exertion Scale (RPE) for 2.5 minutes, and then moderate intensity (RPE of 12) for another 2.5 minutes. After the 5-minute warm-up, volunteers completed the first of eight 30-second runs at a self-selected high intensity (between very hard to extremely hard or ~18 on the Borg Scale) while working against a treadmill load of 2.27 kg. This human-powered treadmill allowed the subjects to quickly reach and maintain their running pace for the 30 seconds while allowing measurement of both distance and force. After the 30-second "run interval," each volunteer completed 1.5 minutes of walking/jogging recovery at an RPE of 12. During these recovery periods, the volunteers either rested their left hand on an empty shelf (control "C" trial), placed it in the 15°C RTX (RTX "R" trial), or rested it on a cold PolarPack Standard Refrigerant Gel Pack (SCA Thermosafe) having a temperature of 15°C (ice pack "P" trial). The PolarPack was replaced after the fourth interval to maintain a constant 15°C. At the end of each recovery period, volunteers rated their level of heat stress using a 0 to 11 numerical scale (3). This 2-minute

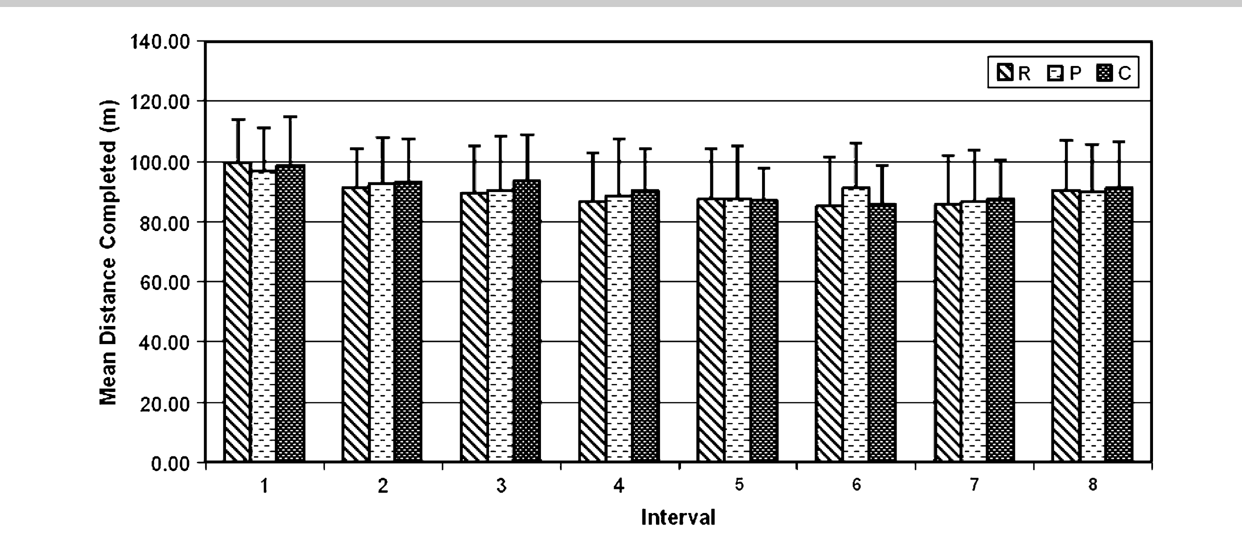

Figure 3. Distance completed per interval for each treatment condition: RTX (R), ice pack (P), and control (C) for $n = 10$.

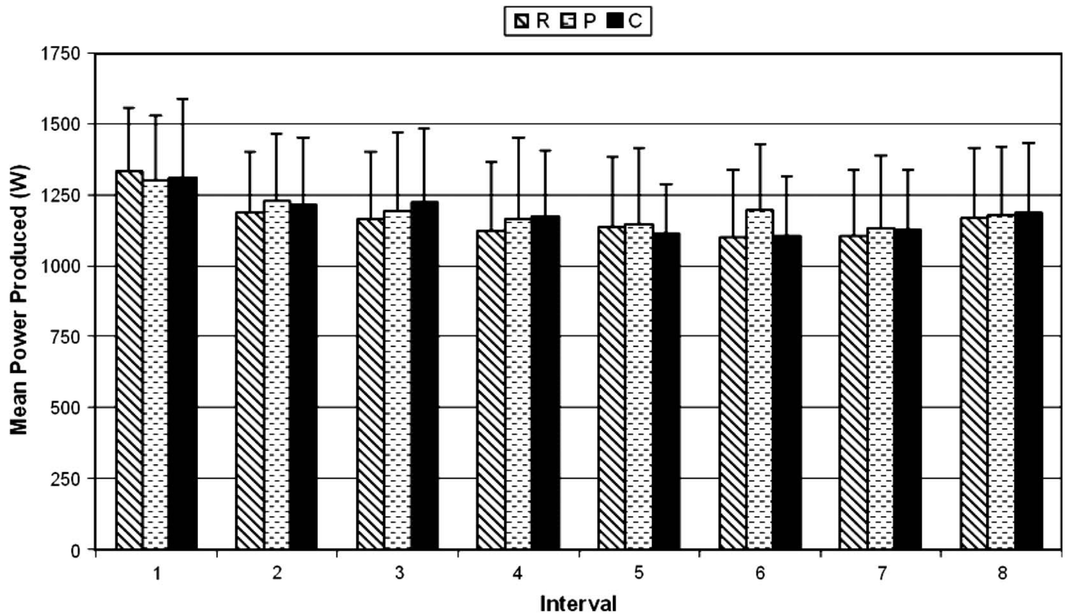

Figure 4. Total distance completed per trial for each treatment condition for each subject: RTX (R), ice pack (P), and control (C).

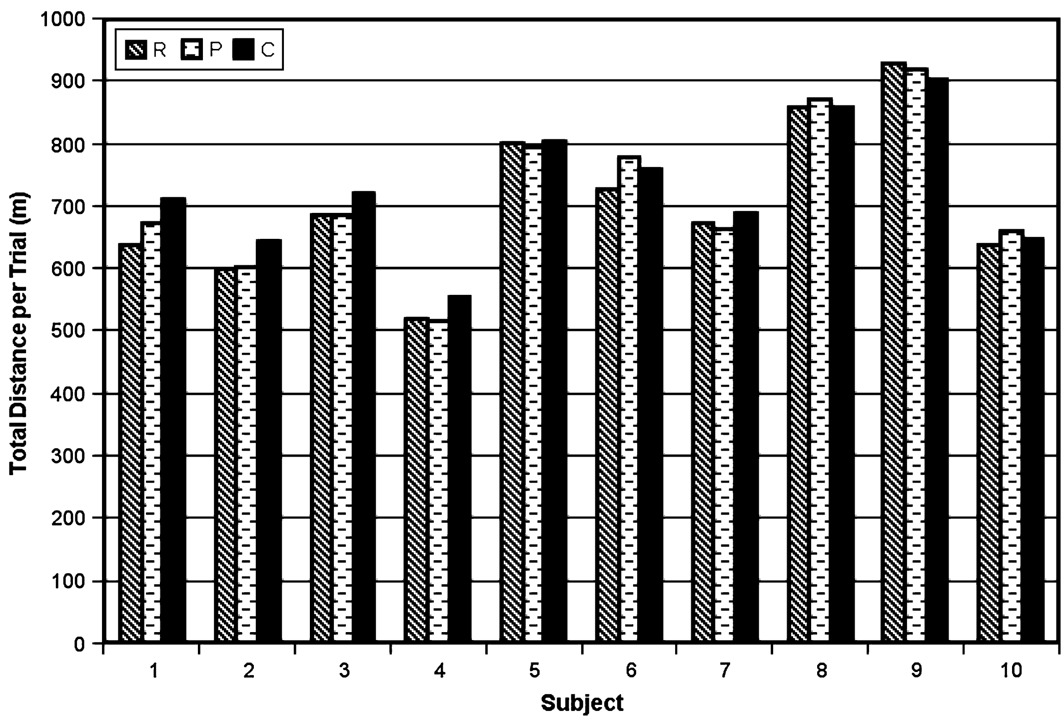

Figure 5. Mean power generated per interval for each treatment condition: RTX (R), ice pack (P), and control (C) for $n = 10$.

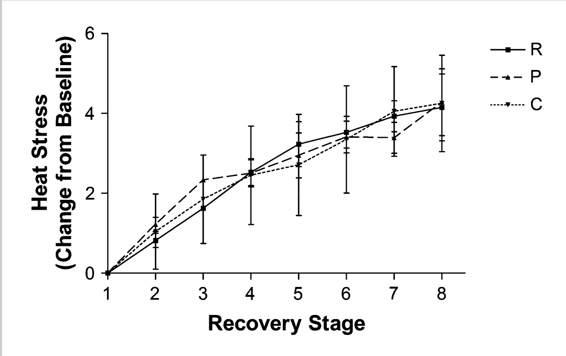

Figure 6. Heat stress ratings expressed as difference from baseline rating per recovery interval for each treatment condition: RTX (R), ice pack (P), and control (C) for $n = 10$.

interval/recovery sequence was repeated 7 more times for a total of 8 complete intervals.

Statistical Analyses

Heart rate, oxygen consumption ($\dot{V}O_2$), T_c, subjective heat stress ratings, distance achieved per interval, and power achieved per interval were collected during the 3 trials (R, C, and P). The measurements were compared between conditions in 2-factor repeated-measures (interval and treatment) Greenhouse-Geisser analyses of variance (ANOVA) using SPSS 11.0 statistical software (SPSS, Inc, Chicago, Illinois, USA). The level of statistical significance was set at $\alpha < 0.05$.

An N of 10 was determined as appropriate to provide 80% power to detect a 0.5°C T_c difference between 3 repeated-measures trials at an α level of 0.05. Standard deviations were taken from a recent study (4) that utilized the CorTemp system to monitor T_c.

Results

Although there were differences in T_c, subjective heat stress ratings, distance, and power generated between intervals, there were no significant differences found between treatments for any of these variables, nor was the interaction effect of interval*treatment found to be significant.

There were no differences in individual subjects' body weights between trials. There were no significant differences in T_c (Figure 1), HR (Figure 2), or $\dot{V}O_2$ between intervals or treatments. Total distance completed (m) per trial was 717.1 m ± 124.4 m (Trial R), 724.8 m ± 130.3 m (Trial P), and 728.6 m ± 110.6 m (Trial C). See Figures 3 and 4 for detail regarding distance and power, respectively. Figure 5 displays total distance per trial for each subject and demonstrates that none of the 10 subjects could be considered RTX-responders. Change in T_c (°C) from baseline to end-test averaged 1.41 ± 0.37°C (Trial R), 1.41 ± 0.39°C (Trial P), and 1.41 ± 0.59°C (Trial C).

Subjective heat stress ratings are shown in Figure 6. Because subjects' ratings of subjective heat stress at time = 0 were not uniform, we used the change from baseline as our measure. (Please note that to improve readability, bars representing standard deviation have been limited to 8–20 representative cases for all graph plots.)

Discussion

The primary finding of this investigation is that use of the RTX device during recovery periods did not delay an increase in T_c, nor did it improve performance of high-intensity intermittent running as compared with ice pack and control treatments. Additionally, subjects reported no difference in their subjective ratings of heat stress between conditions.

Our results were disappointing given that hand immersion in cool water has been shown to be an effective method for combating hyperthermia (9,12,15). There are 2 potential reasons why the RTX treatment was ineffective: (a) this exercise bout of 30 seconds hard running, 90 seconds easy walking/jogging was not limited by hyperthermia; and (b) the RTX device did not provide a meaningful amount of heat extraction.

The capacity for hyperthermia to impair performance of high-intensity intermittent exercise has yet to be determined with complete certainty. Cheung and Robinson (5) found no benefit to pre-cooling subjects prior to repeated cycling sprints in a normothermic environment. Conversely, but with a similar implication on the capacity for hyperthermia to impair performance of high-intensity intermittent exercise, Linnane et al. (14) observed a benefit to pre-heating subjects prior to sprint cycling performance. Their subjects completed two 30-second cycle sprints at an environmental temperature of 20.6°C with a 4-minute recovery between sprints after undergoing immersion up to the neck in 43°C water for 16 minutes and then sitting in an environmental chamber at 44.2°C for 30 minutes. This treatment increased T_c by 1°C over control. The authors theorized that such a difference accounted for an improved first sprint in the pre-heated trial. However, there were no differences in sprint performance in the second sprint in the hot trial compared to the control trial (e.g., the pre-heated cyclists degraded more quickly than the controls). Moreover, mean power was significantly reduced from the first to second sprint in the hot condition but not in the control condition, suggesting that environmentally induced hyperthermia might decrease performance in repeated efforts. Because the current study used a running test rather than cycling, our mean power per sprint (1,180 W) was substantially greater than observed by Linnane et al. (664 W) (14). However, the effort levels emitted by the subjects were similar. In the current study, mean power was reduced between sprints 1 and 2 in all conditions and generally declined over the course of the 8 intervals.

Some of the most compelling evidence to date regarding the influence of hyperthermia on intermittent exercise comes from Drust et al. (6) in a study wherein subjects completed 40 minutes of intermittent cycling (alternating 15 seconds of high-intensity exercise and 15 seconds of rest), followed by

5 × 15-second maximal cycle sprints in both normal and hot environments. They observed significant declines in power over the course of the sprints in both conditions with a significantly larger decline in work during the last 4 sprints in the heat vs. in the normal temperature environment. This decline corresponded with a 2.5°C increase in T_c. (In the control condition, a 1.2°C increase was observed.) Based on this evidence it appears that hyperthermia does limit performance of high-intensity intermittent exercise. Morris et al. (16) reported similar results from a study in which subjects performed a sequence of walking, sprinting, cruising (85% $\dot{V}O_2$max), jogging (45% $\dot{V}O_2$max) and resting, repeated until volitional exhaustion. Subjects were able to repeat this sequence significantly longer at 17°C than at 33°C.

We conducted our trials at a relatively normothermic temperature (~22°C), largely to represent conditions commonly experienced during voluntary physical fitness training, and therefore did not impose as great a thermal burden as did the "hot" trials of Morris et al. (16) and Drust et al. (6). Although we did not attempt to determine what extent hyperthermia vs. other factors (e.g., acidosis) contributed to the erosion of performance we observed in the current study, the fact that we did see such erosion supports the conclusions of those studies. Further, the performance decrease we observed, coupled with the observed significant increases in T_c (1.4°C above baseline) and subjective heat stress, over the progression of intervals indicates that thermal stress was a limiting factor to performance.

If hyperthermia limits the performance of high-intensity intermittent exercise yet there were no differences in performance between our treatments, we must not have induced meaningful heat extraction in any treatment/condition. This could be a result of several factors, including insufficient temperature gradient, insufficient surface area cooled, insufficient amount of time spent cooling, and/or insufficient vasodilation in the cooled area.

Duffield et al. (7) failed to observe a difference between performance of subjects wearing an ice cooling jacket both before (for 5 minutes) and in the recovery periods (2 × 5 minutes and 1 × 10 minutes) of an 80-minute intermittent, repeat sprint cycling exercise protocol inside a climate chamber set at 30°C and 60% RH. They suggested that longer periods of cooling may be necessary to produce a change. Likewise, Grahn et al. (11) reported that the RTX had little effect on the increase in T_c early in their exercise bouts but substantially attenuated the increase in T_c in the later bouts. Our 1.5-minute recovery periods were substantially shorter than those used by Duffield et al. (7) and may not have been long enough to have a measureable action.

The RTX, in its current design, cools the palm of 1 hand. That may not be sufficient surface area to induce a reduction in T_c. Although both Hsu (13) and Grahn (11) observed the RTX to be effective while cooling a single palm, Giesbrecht et al. (9) observed that during rest periods following heavy work in hot, humid conditions, hand immersion in 20°C water did not reduce core temperature as compared with control. However, including forearm immersion with hand immersion did significantly decrease core temperature below control values. Similarly, Balldin et al.(3) observed that a cooling vest circulating 20°C water had a significantly greater effect on T_c, HR, and subjective ratings of heat stress than did use of the RTX circulating 20°C water.

House et al. (12) demonstrated that the colder the water used in the cooling process, the better it effectively cools. Their subjects, after 45 minutes of work at 40°C, rested in the heat for 30 minutes while their hands were immersed in cooled water. After 20 minutes of hand immersion, mean T_c dropped from 38.5 to 36.9°C using 10°C water, to 37.3°C using 20°C water, and to 37.8°C using 30°C water. Livingstone et al. (15) had previously conducted a similar investigation and also concluded that the amount of heat lost during immersion was greatest if the immersion bath was set at 10°C and heat loss decreased as the temperature was set at higher levels (up to 30°C). The RTX used in the current study has a temperature range of 15 to 28°C and was set at 15°C during recoveries in hopes of creating an effectual gradient. Despite this relatively low setting, we failed to observe any perceptible cooling.

Grahn et al. (11) observed that the effectiveness of the RTX decreases in an exponential manner with increasing exercise intensity. The exercise protocol in the current study was of a much greater intensity for a shorter duration than the protocols that have reported a significant cooling effect of the RTX. For example, in the study conducted by Hsu et al. (13), subjects cycled at a 60% $\dot{V}O_2$peak for approximately 60 minutes, whereas in the study by Grahn et al. subjects walked at a moderate rate until their HR reached 90% of the predicted maximum, which occurred between 34 and 57 minutes of continuous exercise. The intensity level of the exercise in the present study was very high. It is likely that the high stress of the sprint bouts caused arteriovenous anastomoses in the hand to constrict during the sprints and remain constricted throughout active recovery periods despite the vacuum produced by the RTX.

Practical Applications

The current study supports the notion that high-intensity intermittent running performance is limited by increases in T_c. Trainers and athletes should expect repetitive sprint performance in hot environments to degrade substantially more quickly than in cool environments in much the same way continuous exercise does. For optimum training effect of sprint-type intervals, we recommend performing sprint training in relatively cool environments and attempt to induce cooling during recoveries. At this time, devices/methods other than the RTX should be used to promote such intra-interval cooling. Devices/methods that affect as large a skin surface area as possible are likely most effective. Additionally, the increases in T_c observed in this study imply that cool-environment interval sprint training may be an effective heat-acclimatization method. Finally, and perhaps most important, trainers and athletes should realize that a comfortable temperature environment does not preclude the potential for exercise-induced heat injuries. Prudent monitoring of T_c and/or other indicators of hyperthermia may be warranted when performing intermittent high-intensity exercise in all ambient conditions.

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